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EROSIVE AGENTS IN THE ARID REGIONS.

BY RALPH S. TARR.

AMONG the mountains in the western part of the United States the agents of erosion are not unlike those of the moister sections of the east. Rain, snow, ice and frost are the chief factors in the sculpturing of these mountain masses.

On the plateau the conditions are different. Snow and ice are rarely seen; frost seldom appears, owing to the extreme dryness of the atmosphere, and rain falls under peculiar conditions. In all climates the action of animals and plants, of sun and air, are important factors in the wearing away of land masses; but in few places are the effects of these agents so important as in the western plateau region. Most if not all the agents of erosion which I shall describe have been noticed and mentioned by the various writers on the geology of the arid regions; but their importance seems so great that it may be well to group them and call especial attention to them.

Of the physical agents, as in all sections of the world, except the most arid, rain is the chief. For fully nine months in the year little or no rain falls upon the truly arid belt. When, during these months, rain falls at all, it comes simply as light showers or brief drizzling rain, producing almost no geological effect. It is absorbed by the soil, and is rarely in sufficient quantity to freshen the parched vegetation.

During the three summer months the region is liable to excessive local rains, often called "cloud-bursts." Several inches frequently fall in an hour during such a shower. Two-thirds of the annual precipitation falls in a few such rains. The geological effect of so much water suddenly poured upon the ground is intense. The whole soil is completely wetted for a depth of several feet, and even in this dry region torrents flow tumultously to the streams. The arid plateaux are chiefly regions of young drainage, on which there are large tracts without drainage arteries.

When a cloud-burst falls upon such a place deep ravines or "arroy s" are suddenly formed by the rush of the waters. Sometimes an "arroyá" fifteen feet deep is cut out in the soil for a distance of a mile. The destructive effects of such a cloud-burst are great, particularly when it breaks upon high ground and flows upon a plain. In July, 1886, I witnessed the effects of such a torrent in the Rio Grande Valley, in New Mexico. The cloud-burst broke upon the low Donna Anna mountains, but no rain fell outside of their limits. The mountains were capped by a dark thunder cloud, while in the valley at Donna Anna, about six miles distant, the sky was cloudless. In a short time a wall of muddy water a foot high spread over the flood plain of the Rio Grande near Donna Anna, and this was followed by similar waves for a half-hour. At Donna Anna, which is situated on a bluff bounded on the south by an "arroyá," a body of water completely filling the arroyá was seen to pass by for about a half-hour, then the body of water gradually diminished to a trickling stream, and in less than an hour no water was flowing. The depth of water must have been twenty feet at this point. It cut under the cliff on which Donna Anna is built, and scaled off a large piece, leaving a house on the edge of a precipitous wall. The stream carried vast quantities of bushes, roots and clay, and, I am told, some animals. On the flood plain several acres of vineyard were completely covered with silt and gravel, one or two small orchards were partially buried, and an adobe house about ten feet high was buried to within two feet of the top. Several thousand tons of earth must have been removed during this torrent. Such floods are not uncommon in these arid regions, and their intense erosive activity may be seen by this illustration.

Next in importance to rain is the direct effect of the air as an erosive agent. In many places in the arid territories extensive sand dunes are proofs of this æolian action; but these are merely grand illustrations of a common phenomenon. During all months of the year dust is being blown about either in clouds or in creeping waves along the surface of the ground. In the valley of the lower Rio Grande, in New Mexico, often for several days in succession strong winds blow clouds of dust along the mesa, and these are often so dense that the Oregon Mountains, ordinarily plainly visible, are completely obscured from view. On the upper Rio Grande, at Embudo, in March, 1889, clouds of dust not uncommonly swept up the cañon, obscuring the high canyon walls from view, although they were only a mile distant. In February of the same year I encountered a dust storm in the pass among the White Mountains, near Fort Stanton, New Mexico, which lasted for several hours. The wind was blowing at a velocity of sixty miles an hour, and not only sand but small bits of gravel were blown with such force as to produce a painful blow on the face. The road could not be seen for a distance of twenty feet. Fine particles of dust penetrated to the works of my watch and caused it to stop.

Another common phenomenon of aerial erosion is the formation of small whirlwinds, to be seen on all sides on the plateau during the summer time. These sometimes gather force enough to carry away small bushes. The creeping action of blowing sand I have often had forcibly illustrated, when during a windy night the sand has blown upon my blankets, and formed a thin coating of sand.

The direct effect of change in temperature must be an important geological agent. On the plains the temperature of the sand is often 115° during mid-day, while in the early morning it may be as low as 60°. During the winter a black bulb thermometer registered 105° at one o'clock, while the minimum temperature at night was 27°. Such an excessive thermometric range must aid greatly in breaking up the rocks, especially the black basalts so common in the west.

Organic aids to erosion are also important. Plants serve very slightly in breaking up the soil. They grow with extreme slowness and great difficulty. They are important more in a conservative than a destructive way. The vegetation is thin and scanty, and hence does not act as a protective covering to the extent that plants of a moister climate do. The conservative effect is well shown, however, in the case of the mesquite, which catches and holds down the blowing sand, and as a result often causes to be built around it a bank of sand many feet high, often fifteen or twenty feet. The mesquite, and indeed almost all arid land-plants, have great root extension, by far the greater part of the plant being beneath ground, and the disintergrating offect of this peculiarity must be considered.

Among animals there are at least three types which are doing much work of erosion. Formerly the bison, and now their successors,—cattle,—have done an appreciable geological work. In the formation of trails and the general tramping of the ground they have aided in protecting the soil against the action of wind and water. Recently in southern New Mexico, on the Pecos, I have had my attention forcibly called to the importance of cattle in this direction. Several small streams had their course considerably lengthened by the puddling of the stream-bed by cattle.

Ants are very abundant on the plateau, and they are continually at work tunnelling the soil and bringing fresh earth to the surface. On the upper Rio Grand, near Embudo, there is a clayey gravel containing many small garnets. The ant-hills in the vicinity are composed chiefly of garnets. The clay is apparently washed out, and the coarser particles have remained. Ant-hills are frequently washed away during a rain, but they are quickly rebuilt. A peculiar ant, the "agricultural ant," so called, is common in the south-west. These creatures have a clear space around their homes, thus exposing the bare ground to the action of the elements.

The work done by prairie dogs, while in individual cases apparently insignificant, must amount to a grand sum total. Over large tracts their burrows open to the air at intervals averaging not more than twenty-five feet apart. I have no means of telling how far they extend into the ground, but from the appearance of their mounds I should judge it to be only a few feet. This mound rarely exceeds a height of two feet, and generally less. Being in the form of a truncated cone, with a very gradual slope; they are sometimes three feet in diameter. Their burrow is seldom more than six inches wide, so that its extreme length cannot be many feet. That the creatures are constantly at work is proved by the great number of new holes in every "dog town," and also by the number of holes in old roads passing through sections inhabited by the prairie dog. Deserted burrows can always be told by the destruction of the mound, and widening of the hole under the influence of subaerial denudation. The towns are generally built on gentle sloping hills, where there is some drainage, consequently the fresh clay and earth brought to the surface is gradually drifted away. Not only is the work of erosion aided by the bringing up of material to the surface, but also by the opening of tunnels, by which water is allowed free underground passage. With a mound around the hole this inflowing of water is reduced to a minimum; but when the hole is abandoned, and the mound destroyed, water freely enters, and in such cases I have frequently noticed small runlets leading to the hole.

Thus it will be seen that the great agent of erosion, water, is of particular importance in the arid regions on account of its intensified action during brief periods; that the direct effect of aerial currents is a powerful factor in the erosion of these plateaux; that the sun's heat must also play an important part; that plants are only slightly conservative and slightly destructive; and that animals, by tramping down the soil or by burrowing and tunneling into the earth, are important aids in the great work of subaerial denudation by which the plateaux of the west are being gradually eaten away.